CHAPTER 3

FUEL BURNING EQUIPMENT

Section I. COAL STOKERS

3-1. General.

Stokers may be divided into four general classes: underfeed, spreader, travelling or chain grate, and overfeed. Generally, domestic type boilers use single-retort underfeed stokers and therefore, only this type is discussed.

3-2. Single-retort underfeed stokers.

This unit consists essentially of a coal hopper, a screw for conveying coal from hopper to retort, a fan which supplies air for combustion, a transmission for driving the coal feed worm and electric motors supplying power for coal feed and air supply. Air for combustion is admitted to the fuel through tuyeres at the top of the retort. The retort may be either round or rectangular. The stoker feeds coal to the furnace intermittently in accordance with temperature or pressure demands. A special time or holdfire control is used to maintain a fire during periods when heat is not required. Figure 3-1 shows a typical arrangement.

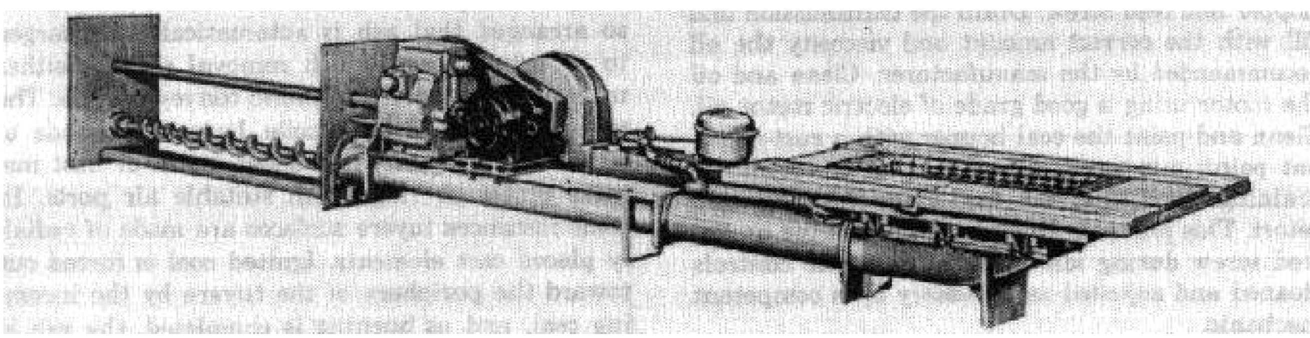

Figure 3-1. Single retort screw feed stoker.

3-3. Operation.

Two main causes of excessive outage and maintenance are sustained or frequent overloading of stoker and operating with insufficient draft. Where prolonged overloading is unavoidable, good operation and careful attention to maintenance are important.

a. Fire. Following are the main points to keep in mind for maintaining a good fire.

(1) Keep fire out of retort. This condition can result from a fuel bed which is too thin, from banking with insufficient fuel or from running with an empty hopper.

(2) Avoid working the fire too much. If the fuel bed requires leveling off, use a light rake or bar on the surface of the fire. Never slice the fire as is done in hand firing by pushing a bar under the fire and raising it through the fuel bed.

(3) Be sure to feed sufficient fuel when banking. It may be necessary to renew the fuel supply during long banking periods.

(4) The depth of the fuel bed is very important. If too thin, the fire may burn down into the retort and damage it. If too heavy, poor air distribution will result, causing spotty, uneven fire, holes in the fuel bed, smoke, and reduced efficiency. The correct depth of the fuel bed above the top of the retort may be anywhere from 4 to 8 inches, depending upon analysis and burning characteristics of the coal used.

b. Draft. Check with draft gauge and a carbon dioxide ($C0_2$) indicator.

(1) Operate with a slight draft, preferably not less than 0.02 inch water gauge just above the fuel bed. Positive pressure will cause excessive temperatures at grates and lower wall areas.

(2) Maintain a proper supply of air at all times. Either too much or too little air will reduce efficiency and capacity.

(3) Do not force the stoker beyond the capacity of the stack to carry away flue gases.

(4) Keep wind boxes properly sealed to prevent leakage of air into the ash pit and furnace.

(5) If the draft is insufficient, check leaks in setting and losses through boiler and flue connections. Check the position of the boiler damper.

c. Cleaning.

(1) Remove siftings from wind boxes often enough to prevent any possibility of fire under the hearth. Frequency of cleaning depends upon type of fuel used, but wind boxes should be inspected often.

(2) Keep the front of the stoker clean to prevent contamination of lubricants and excessive wear on moving parts.

d. Lubrication. Use proper lubricants at sufficiently frequent intervals at all points requiring lubrication to avoid unnecessary outages and excessive maintenance. Prepare a definite schedule for lubrication and adhere to it regularly. Manufacturer's literature should be consulted when setting up the lubrication schedule.

e. Lay-up. When stokers are to be out of service for long periods of time, remove coal from the hopper and feed screw. Drain the transmission and fill with the correct amount and viscosity the oil recommended by the manufacturer. Clean and oil the motor using a good grade of electric motor oil. Clean and paint the coal hopper with a rust-resistant paint; mix sawdust and fuel oil or crankcase drainings and fill the feed-screw housing and retort. This prevents moisture from forming on the feed screw during idle periods. Have the controls cleaned and adjusted as necessary by a competent mechanic.

3-4. Inspection and maintenance procedures.

Following is a description of good practices for inspection and maintenance of coal stokers:

a. Inspect all accessible parts of the stoker often. Inspect thoroughly at scheduled intervals.

b. During routine and daily inspections, look especially for loose bolts and loose connections in moving parts. Where movement is transmitted by a shear pin or safety release be sure there is no binding which prevents protective device from serving its function. Make repairs or replacements promptly.

c. When the stoker is shut down, make a thorough inspection. Check for wear on moving parts and check alignment. Check condition of dump grates. On stokers equipped with moving grate bars, check movement of bars to see that proper clearances are maintained. Overall clearances to provide for elongation of grate bars should be 1 ½ inches on small stokers, and up to 2 inches on larger stokers.

d. Inspection and maintenance procedures for anthracite coal stokers in domestic type installations are similar to that for bituminous coal stokers previously described. However, some units are so arranged that ash is automatically discharged to an ashpit, from which removal may be either manual or by small automatic conveyor units. The tuyere surface of anthracite burners is made of either formed perforated sheet metal or cast metallic plates or rings with suitable air ports. In some instances tuyere surfaces are made of radially placed cast elements. Ignited coal is forced out toward the periphery of the tuyere by the incoming coal, and as burning is completed, the ash is discharged by gravity from the ash ring into an ashpit under the stoker retort. To avoid discharge of unburned coal to the ashpit, adjust the rate of coal feed and air supply carefully.

3-5. Troubleshooting underfeed stokers.

A troubleshooting chart for underfeed stokers is in appendix B.

Section II. HAND-FIRED COAL BURNERS

3-6. General.

In coal burning installations, units may be hand fired using either updraft or downdraft type furnaces. In both types, coal is fed manually onto grade bars forming the bed of the furnace. There are limitations to the combustion capacity obtainable with hand firing in a single heating unit; this firing method is employed only with the smallest units.

3-7. Furnace types.

a. Updraft furnace. Updraft type furnaces are most commonly used in the types of military installations covered by this manual. Primary air enters the lower portion of the furnace and passes up through the fuel bed. Stationary grate bars permit primary air to rise and ash to drop through. The fire must be cleaned manually with special tools. Sometimes dumping grates are used which permit mechanical removal of ash and refuse without opening fire doors. Typical grates used in this type of furnace are shown in figure 3-2.

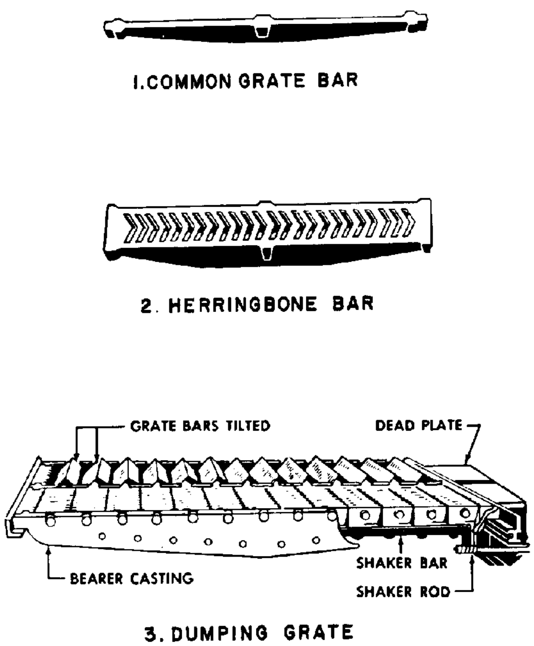

Figure 3-2. Grates for updraft furnaces.

The grate, which supports the fuel bed and admits air for combustion, is made up of a number of bars supported at the rear by the bridge wall and at the front by a dead plate which, in turn, is supported by the brickwork. The grate bars are held in place by their own weight. The types of grates commonly used for updraft furnaces are the common grate bar, herringbone or tupper bar and dumping grate.

(1) The common grate bar (figure 3-2.1) is usually about three feet long and three inches deep at its center. The width varies from ¾ inch at the top to ¾ inch at the bottom. This grate allows the air to rise and the ashes to drop through.

(2) The herringbone or tupper bar (figure 3-2.2) is about six inches wide with side flanges to prevent warping. Each bar has V-shaped openings running the length of the bar for passage of air and ash.

(3) The dumping grate (figure 3-2.3) permits removal of the ash and refuse without opening the firing doors and also reduces the amount of labor required. Tools used to handle the fire are the hoe, slice bar, and rake. The hoe and slice bar are used to clean the fire and break the clinkers. The rake is used to level off the fuel bed. The bridge wall keeps the fire on the grates, assists in mixing the air and gases, and directs them over the heating surface.

b. Downdraft furnace. The downdraft furnace (figure 3-3) has both an upper and lower grate and gets its name from the fact that primary air passes down through the fuel on the upper grate. The upper grate consists of a series of tubes which extend from the front water leg to a header in the rear. This header extends from one side water leg to the other, and supports a refractory wall which forms the back of the downdraft furnace. The lower grate is formed by common grate bars or by a regular shaking grate. Coal is fired through the top doors onto the upper or downdraft grate where it burns. Incandescent fuel drops through to the lower grate where it keeps a bright fire. Air is admitted above the upper grate and mixes with the distilled gases from the coking coal as it passes down through the upper grate. The incandescent fuel bed on the lower grate helps to complete the combustion of volatile matter given off by the coal and reduces emission of smoke from the boiler. This type of furnace cannot be used where high rates of firing are necessary.

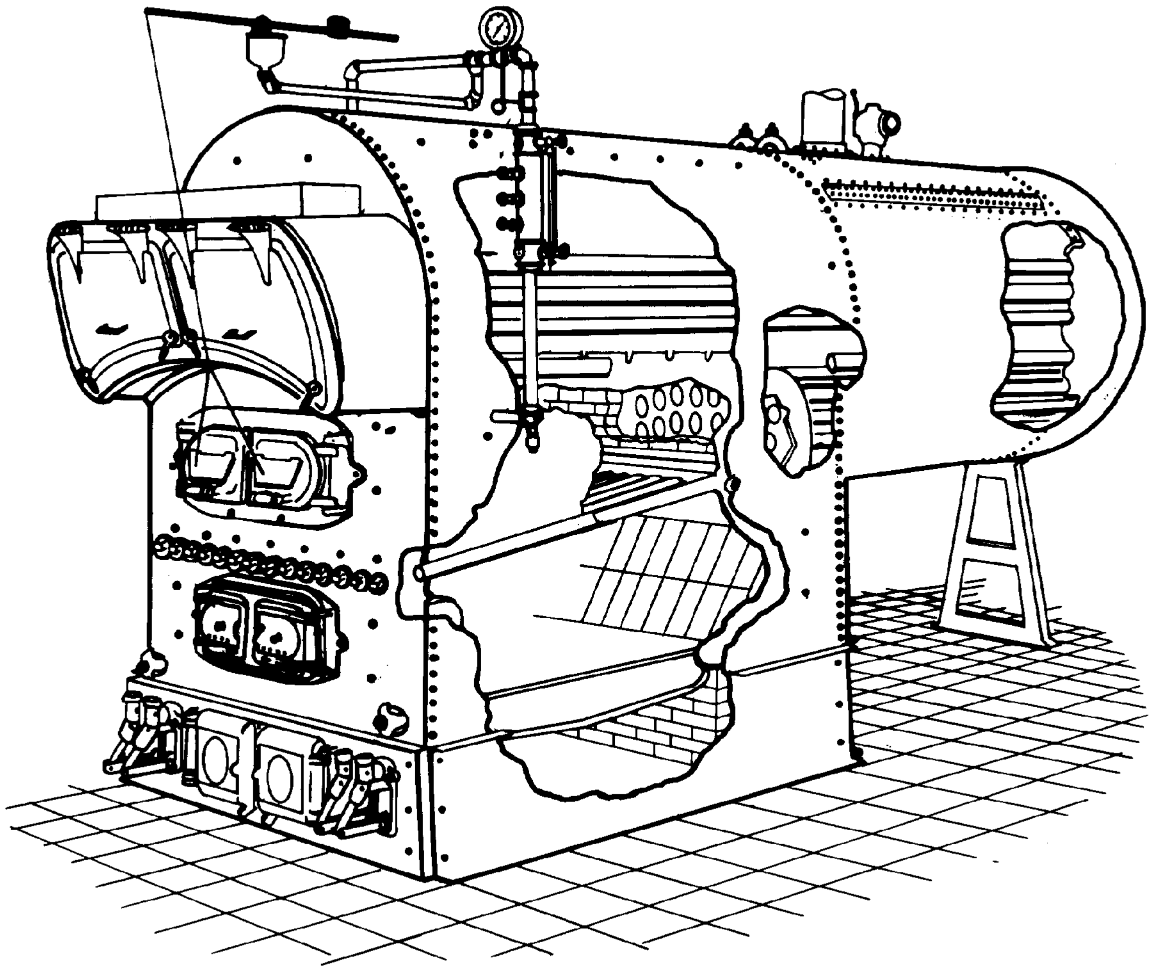

Figure 3–3. Downdraft furnace.

3-8. Operation.

In hand firing, the best condition of the fuel bed is obtained when coal is fired frequently, in small amounts, with proper distribution; when caked masses are broken up immediately; and when ash and clinkers are not allowed to clog the bed. In general, there are three methods of hand firing.

a. Spread firing. A small amount of the fresh coal is distributed evenly each time over the entire surface of the bed. This method is commonly adopted with anthracite and other low-volatile coals.

b. Alternate firing. New coal is placed on selected areas of the grate each time. The coal may be placed alternately on one half of the grate, on alternate strips, or on alternate spots. This method of stoking is particularly suited to non-caking coals.

c. Coking-firing. Fresh fuel is placed on the front edge of the fuel bed and allowed to cake there, the volatile matter passing back over the hot bed. After the distillation is complete, the remaining carbonized fuel is pushed back and distributed over the bed. This method, while effective, does not permit obtaining high rates of combustion compared to the other methods.

(1) The best firing condition for a hand fired furnace is obtained when fresh coal is added at or shortly after completion of distillation of the previous charge. Optimum intervals between firing are approximately ten minutes for bituminous coals, and slightly less frequently for less volatile semibituminous and anthracite coals.

(2) The bed thickness for best results depends on many factors, including the kind, size and condition of coal, the characteristics of the ash, the draft available and the loading. In general, with natural draft, bed thicknesses range from four to eight inches with run-of-mine bituminous coal and with anthracite buckwheat. Bed thicknesses range from 10 to 14 inches for semibituminous coals. With heavy loading, however, it may be desirable to

use a relatively thin fuel bed to increase the flow of primary air obtainable with the available draft. In all cases, bed thickness for a given type of furnace and coal is best determined by experiment.

Section III. OIL BURNERS

3-9. General.

Most modern oil fired furnaces and boilers used at Army installations have gun type burners. Horizontal rotary burners may be found on some older heating systems. These two types of burners will be discussed in this section.

3-10. Burner descriptions.

a. Gun type oil burners. Gun type oil burners atomize the fuel either by oil pressure (high-pressure gun) or by low-pressure air (low-pressure gun).

(1) *High-pressure gun burners.* The oil system of a high-pressure atomizing burner consists of a strainer, pump, pressure-regulating valve, shut-off valve, and atomizing nozzle. (See figure 3-4.) The air system consists of a power-driven fan with provision to throttle the air inlet, an air tube surrounding the nozzle and electrode assembly, and vanes or other means to induce turbulence for proper mixing of air and fuel oil. The fan and oil pump are generally directly connected to the motor. Atomizing nozzles are available for various spray patterns and oil rates to suit particular installations. Flame shapes vary depending upon the design of the air exit at the end of the air tube. Oil pressures are generally about 100 psi, but considerably greater pressures are sometimes used. Burner output ranges from 0.5 gph and higher.

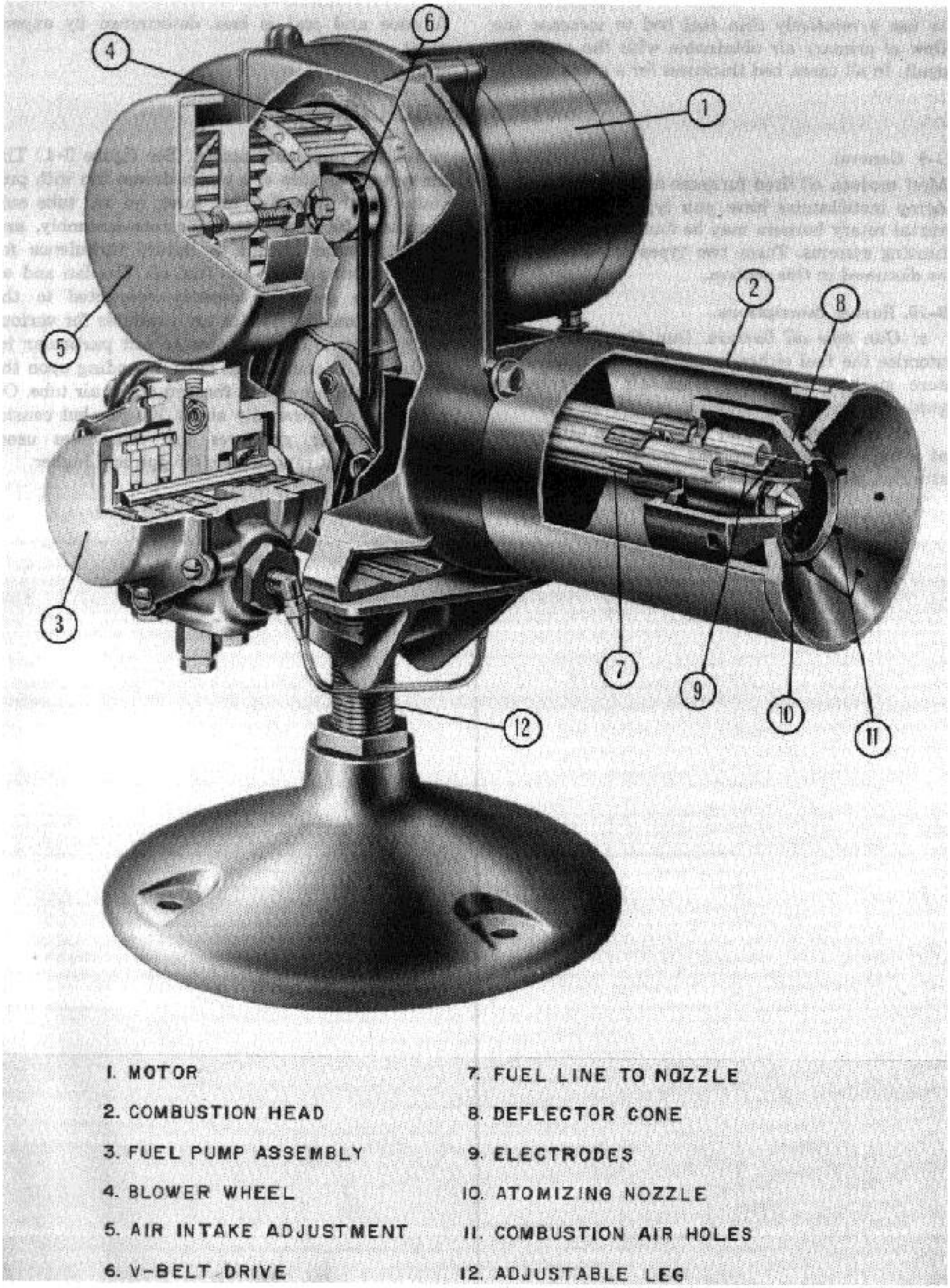

Figure 3-4. Pressure atomizing gun type oil burner.

(2) *Low-pressure gun burners.* This gun type burner uses a portion of the combustion air at relatively low pressures to mix with the fuel oil at the nozzle orifice. Expansion of the compressed air froths or emulsifies the oil and a fine spray is delivered into the combustion chamber. The form and parts of the low pressure air-atomizing burner, as shown in figures 3-5 and 3-6 may be similar to those of the high-pressure atomizing burner except for the addition of a small air compressor and means to deliver the air and oil to the nozzle. The oil pump delivers the fuel oil at low pressure. The nozzle opening is relatively large because of the low pressure and the increased volume of the air-oil mixture. Electric ignition is almost exclusively used. Electrodes are located near the nozzle, but out of the path of the oil spray. Minimum burner output is approximately 20 gph so that this type burner is used only for very large furnaces.

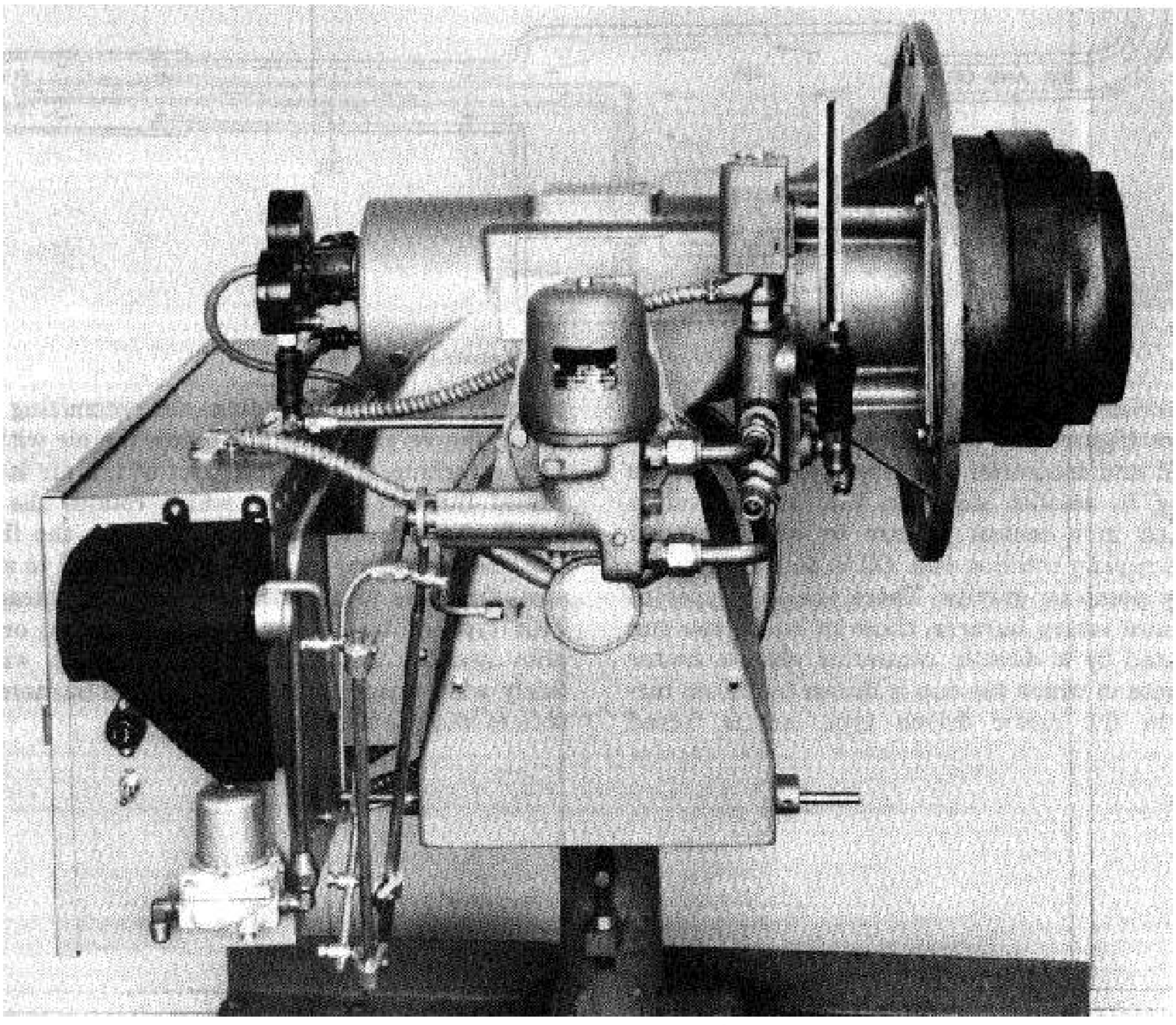

Figure 3-5. Air atomizing gun type burner.

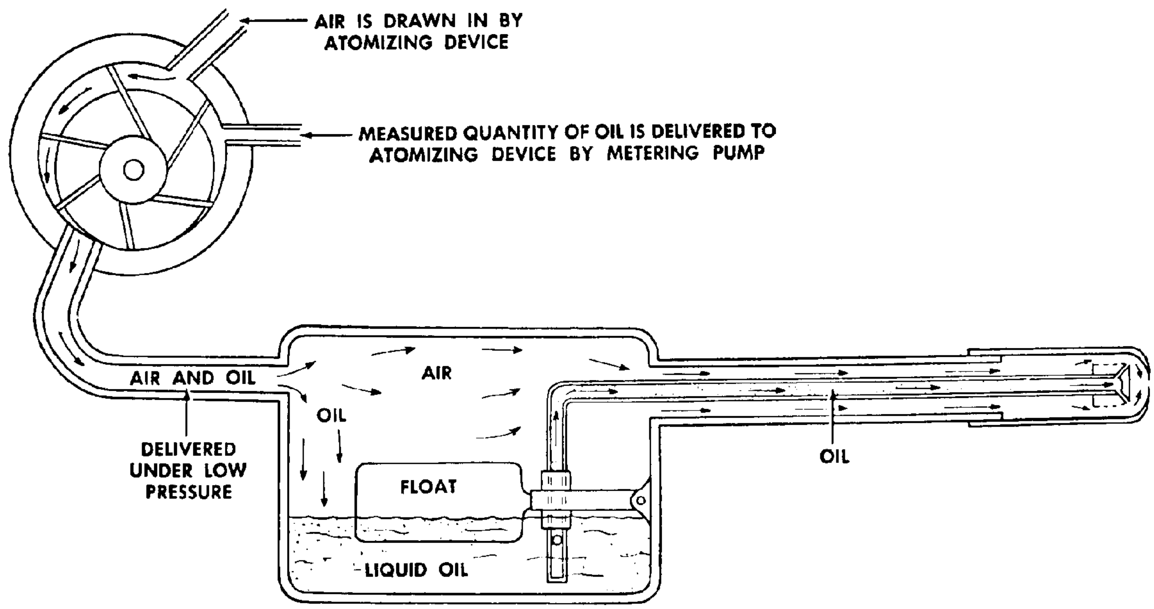

Figure 3-6. Operating principles of low pressure gun type burner.

b. Horizontal rotary burners. Horizontal rotary burners (figure 3-7) originally designed for commercial and industrial use, are used for domestic heating in smaller sizes. In this burner, oil is atomized in a conical pattern by being sprayed from a rapidly rotating cup. Oil is delivered to the cup by pump or gravity. There are two types of horizontal rotary burners, those in which the cup is rotated by a directly connected electric motor and those in which the cup is driven by an air turbine. In the motor driven type, air is forced through vanes surrounding the atomizing cup which shapes the flame and mixes the air with oil. In the turbine driven type, part of the air is first passed through a turbine which rotates the cup, and is then directed to properly shape the flame. Horizontal rotary burners are constructed to swing away from the furnace for inspection and cleaning. This type of burner employs gas-electric or gas pilot ignition and operates satisfactorily with a fairly wide range of fuels. Large size burners are able to atomize heavier oils.

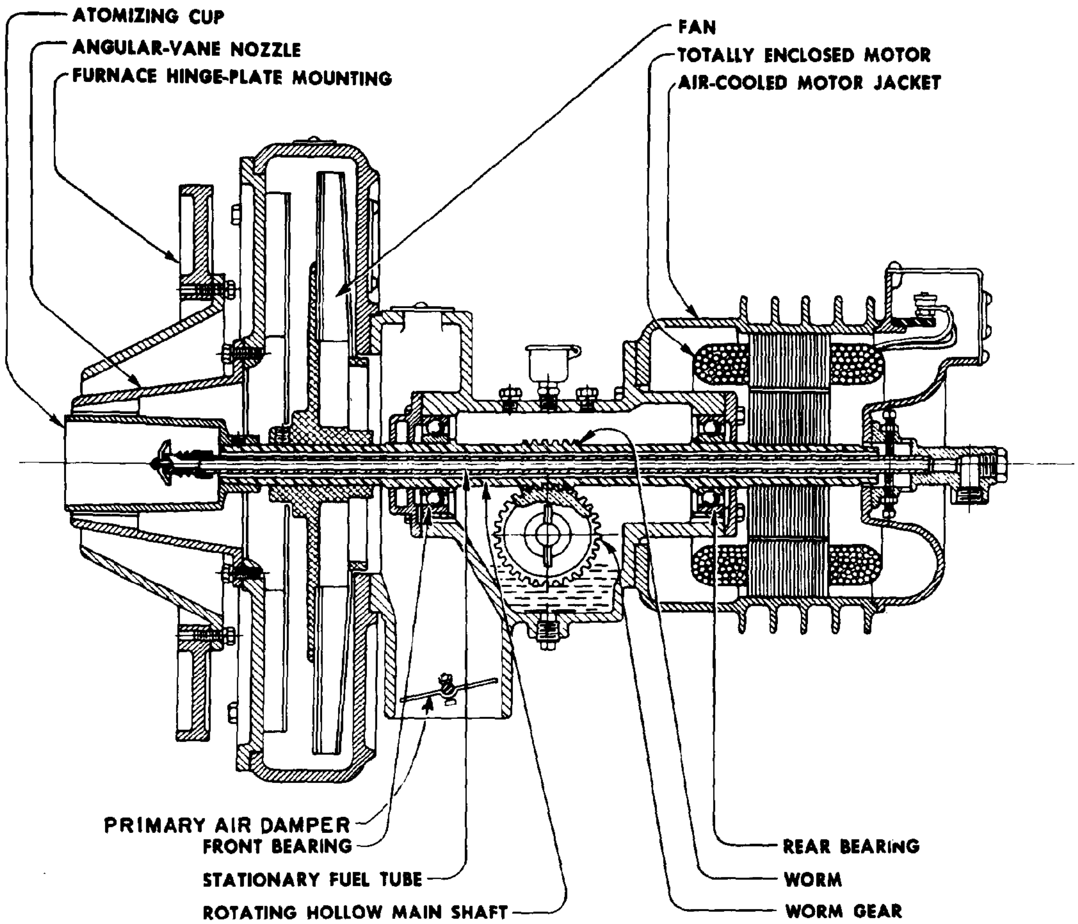

Figure 3-7. Horizontal rotary oil burner.

3-11. Ignition procedures.

Domestic oil burners vaporize and atomize the oil and deliver a predetermined quantity of oil and air to the combustion chamber for combustion. Oil burners for boilers and warm air furnaces operate automatically and maintain a desired temperature.

a. Oil pressure. Pressure must be sufficient to properly atomize the fuel oil and to provide flow of fuel to the atomizing head at a minimum velocity consistent with efficient operation. Generally, No. 1 oil will work well in small burners provided it contains a lubricant to lubricate the pump. A comparatively heavy oil will allow flow through a given nozzle somewhat in excess of the rating stamped on the nozzle. Heavy oils require 100 psi pressures. High pressure plus heavy oil tends to raise the flow rate considerably above the nozzle marking. If the flow is too heavy, a smaller nozzle should be installed.

b. Burner starting The following procedure should be followed to start a gun-type or horizontal rotary burner.

(1) Set draft for 0.02 to 0.04 inch water gauge.

(2) Partly close air shutter.

(3) Check pressure gauge and petcock installation.

(4) Make a cold contact in primary burner control or stack switch by tilting contact carrier to left so contact closes. See instructions from supplier of primary control for this operation.

(5) Close burner switch with thermostat and limit control calling for heat.

(6) Open petcock to expel air from system. Close when oil flow is clear.

(7) If burner stops before oil reaches nozzle, let safety element in stack control cool before pushing button to restart. Do not hold relay in because safety element will become overheated.

(8) Slowly open air adjustment until fire burns clean.

(9) If oil initially discharges into the firebox without igniting because of ignition difficulty or other cause, oil will soak into the soft brick. Be sure relief door is open. Properly ventilate combustion chamber after any misfire. When burner does ignite, shut burner off immediately and allow sur-

plus oil to burn off. Oil-soaked brick will cause the burner to rumble and puff for a few minutes until oil has completely burned out. After any misfire, personnel should stand to one side of the opened relief door to avoid injury from possible backfire.

(10) Make final air adjustment after burner has been running long enough to warm the fire-pot. Look through the barometric draft regulator with a droplight. Reduce the supply of burner air until smoke can be seen passing through the light ray in the smokepipe. Then open the air adjustment until smoke disappears.

(11) After the burner has been visually adjusted and allowed to run for approximately 30 minutes, reduce the stack draft until there is just enough pressure in the firebox to prevent possible increases under unfavorable draft conditions. The draft regulator helps maintain a constant draft regardless of outside weather conditions. Adjust the draft by properly setting the adjuster. Too little draft is likely to cause firebox pressure, odors in the building and possible smoke or smothering of the flame. Excessive draft accentuates the effect of a possible leak, lowers the percentage of CO_2 in the flue gas, and in turn reduces the overall efficiency of the unit. After burner flame and draft are properly adjusted, flue-gas analysis should show a CO_2 content of approximately 10 percent. If it does not, recheck the burner air adjustment and inspect for air leaks. For best results, the flame should be just large enough to heat the building properly in cold weather. Air supplied to the burner should be the minimum necessary for clean combustion.

3-12. Oil burner operation.

The rate of heat production required to maintain desired temperatures varies widely. Some means must therefore be provided to control the rate at which heat is produced. This control may be achieved manually or with automatic controls. There are three firing strategies used in the operation of oil burners.

a. Intermittent. In the intermittent system, the burner operates at a high set rate until the room temperature reaches the desired point. At this point, automatic controls cause the burner to suspend operation completely until lower room temperatures cause it to resume operation. Automatic ignition of the electric or pilot light type is essential to this system of operation.

b. High-low. In the high-low system, two rates of burning are provided, one below and the other in excess of average demand. When room temperatures fall below normal, the burner automatically operates at high flame, and changes to low flame when room temperatures reach a desired point. A modification to this system provides for three ranges of firing.

c. Continuous. In the continuous system, the flame burns continuously but the rate is regulated manually or automatically to meet the heating load.

3-13. Inspection and maintenance of oil burners.

a. Equipment. Each serviceman should have the items listed below to start or to service gun-type and horizontal rotary burners.

(1) Pressure gauge set consisting of 150 psi pressure gauge, fittings and petcock for purging air from oil line when starting the burner. Pressure gauges with ranges as high as 600 psi may be required for high-pressure gun burners.

(2) A full set of Allen setscrew wrenches for the bypass plugs and for adjusting the nozzle holder and electrodes. Use only a socket wrench of proper size for the nozzle. An open end S-wrench is required for nozzle holders.

(3) Small screw driver for adjusting pressure at regulator and for installing and servicing the thermostat.

(4) Pipe dope for use with oil lines. Be sure that it is special oil pipe dope. Use this on all pipe threads.

(5) Complete assortment of nozzles. Nozzles should be replaced as required, rather than cleaned on the job. After a few nozzles are accumulated, they should be cleaned in the shop.

(6) Combustion analysis kit including draft gauge.

b. Cleaning nozzles. Clean nozzles only in the shop on a clean bench. A nozzle is a delicate device and should be handled with care. Use kerosene or safety solvent to cut grease and gum and use compressed air, if available to blow dirt out. Wear goggles to protect the eyes when using compressed air. Never use a metal needle to clean the orifice; sharpen the end of a match, or use a brush bristle for this purpose. Always use a socket wrench when turning the nozzle. Be sure that the nozzle seat is clean. When it comes to “bottom”, back it off and retighten it several times to make a tight oil seal. Exercise care not to strip nozzle threads.

c. *Replacing nozzles.* Select replacement nozzles that have the same capacity and are for the same type oil as the nozzle to be replaced. Also, make certain that replacement nozzle has the same angle of spray and the same spray pattern as the nozzle being replaced. All nozzles are stamped to identify their operating characteristics and capacity. If a nozzle is to be operated at a pressure different than that stamped on the nozzle, refer to table 3-1 to determine approximate oil flow (No. 2 oil) at the desired operating pressure.

Table 3-1. Nozzle Selection Chart for No. 2 Oil

Rating at 100 psi (gph)	Operating—Capacity—(gph)				
	Pressure (psi)				
	75	125	150	175	200
0.40		0.45	0.49	0.53	0.56
0.50		0.56	0.61	0.66	0.71
0.60		0.67	0.74	0.79	0.85
0.65		0.73	0.80	0.86	0.92
0.75		0.84	0.92	0.99	1.06
0.85		0.95	1.04	1.13	1.20
1.00	0.87	1.12	1.23	1.32	1.41
1.10	0.95	1.23	1.34	1.45	1.55
1.20	1.04	1.34	1.47	1.59	1.70
1.25	1.07	1.39	1.53	1.65	1.77
1.35	1.17	1.51	1.65	1.79	1.91
1.50	1.30	1.68	1.84	1.98	2.12
1.65	1.43	1.84	2.02	2.18	2.34
1.75	1.51	1.96	2.14	2.32	2.48
2.00	1.73	2.24	2.45	2.65	2.83
2.25	1.95	2.52	2.74	2.98	3.18
2.50	2.16	2.80	3.06	3.30	3.54
3.00	2.59	3.35	3.68	3.97	4.25
3.50	3.03	3.91	4.29	4.63	4.95
4.00	3.46	4.47	4.90	5.30	5.66
4.50	3.90	5.04	5.51	5.95	6.36
5.00	4.33	5.59	6.13	6.61	7.07
5.50	4.76	6.15	6.74	7.27	7.78
6.00	5.19	6.71	7.33	7.94	8.48
6.50	5.63	7.26	7.96	8.60	9.20
7.00	6.05	7.82	8.58	9.25	9.90
7.50	6.49	8.38	9.19	9.91	10.60
8.00	6.93	8.94	9.79	10.58	11.31
9.00	7.79	10.06	11.02	11.91	12.73
10.00	8.66	11.18	12.25	13.23	14.14
20.00	17.32	22.36	24.49	26.46	28.28
30.00	26.00	33.60	36.80	39.70	42.50
40.00	34.60	44.70	49.00	53.00	56.50
50.00	43.30	55.90	61.30	66.10	70.70
60.00	52.00	67.00	73.50	79.40	84.00
70.00	60.60	78.20	85.70	92.50	99.00
80.00	69.20	89.40	98.00	106.00	113.50
90.00	77.90	100.90	110.50	119.20	127.50
100.00	86.50	111.90	122.50	132.30	141.40

d. Troubleshooting. Following is a description of possible problems and remedial steps that should be taken.

(1) Furnace pulsates on start, stop or during operation.

(a) Check all adjustments of the nozzle-electrode assembly and blast tube in relation to each other and to the firebox. The nozzle and electrode assembly includes oil pipe, nozzle holder, nozzle and strainer, electrodes, glazed porcelain insulators around electrodes, supporting clamp for all parts, and the static disc. The nozzle tip should be back d inch to e inch from the end of the tube. See figure 3-8. For average assembly, ignition points should be c inch apart, c inch ahead of nozzle, and ½ inch to e inch above the nozzle center line.

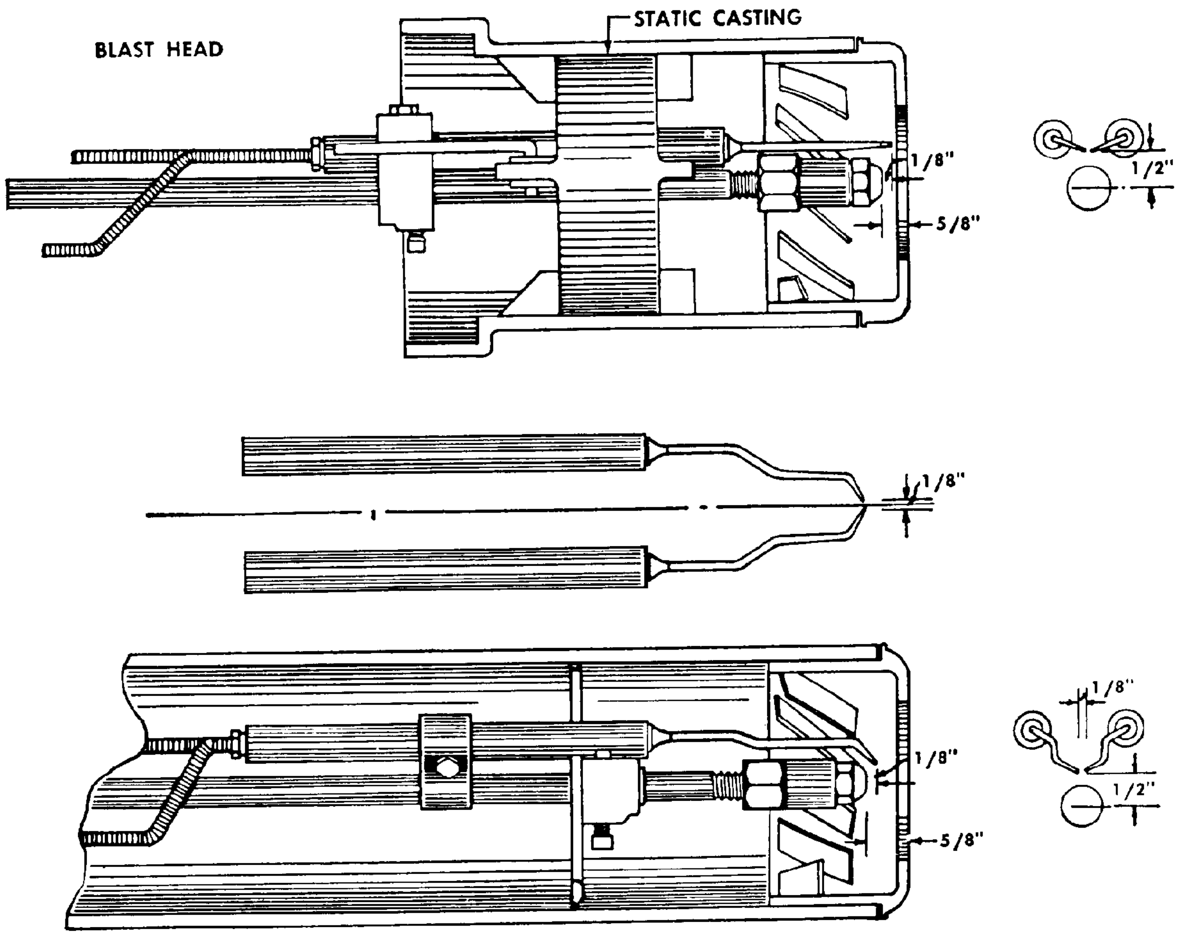

Figure 3-8. Settings of ignition points and nozzle for oil burner.

(b) Be sure that the draft is correct. Make sure that there is no downdraft. If draft is not strong enough, change the setting on draft regulator. Check the chimney to see that there are no leaks to cause poor draft.

(c) Nozzle may be defective. Replace nozzle with a new one.

(d) Be sure air is out of the line between fuel unit and nozzle. Air trapped here will compress during burner stops. This causes oil to squirt at the nozzle when the burner shuts down. Wait a few days after burner installation to make final adjustments. This often allows time for the trapped air to escape.

(2) Flame is raw and stringy.

(a) Be sure the air adjustment is not open too wide. Too much air will make a poor fire and cause surplus raw oil to soak into the fire brick.

(b) Nozzle may be partially plugged. Replace nozzle with a new one.

(c) Be sure that all air is out of the pump. If not, vent with petcock on pressure gauge.

(3) Ignition points collect carbon.

(a) If the nozzle is in good condition, check ignition points, and move them up slightly if they are in the spray. See figure 3-8.

(b) Be sure nozzle is tight in the holder. A leak here will allow oil to escape and carbonize on the electrodes.

(c) Check shutdown of the burner to be sure that the pressure regulating valve shuts off the oil completely.

(4) Noise in the oil pump.

(a) This is usually caused by air in oil lines, a plugged strainer or water condensed in the oil tank which creates excessive suction on the oil line. Purge air from the oil line by loosening the vent plug where the pressure gauge is attached.

(b) Check for leaks in the suction line. Any leaks in overhead piping, above the liquid level in the storage tank, will allow air to enter the oil line.

(c) Clean the strainer in the pump, change the oil line filter.

(d) With some very light oils, an overhead pipe will allow air in the oil to settle out and collect in bubbles. Air can then come through, and obstruct pump action. Two-pipe fuel line systems minimize such danger.

(5) Frequent burner cycling.

(a) Be sure that the heating element in the room thermostat is screwed in tightly. Check wiring; wires may be reversed or spliced incorrectly. The wires may also be reversed at the primary burner control.

(b) Check thermostat adjustment. See manufacturer's instructions packed with thermostat.

(c) Check drive arm adjustment of the primary burner control. See instructions packed with the primary burner control.

(d) Check limit control. If set too low, the burner will shut down before the building can get warm. Filters above blower may be plugged so that there is insufficient air circulation. This will cause the burner to shut down on limit control.

(e) The nozzle may be too large for the unit so that heat buildup is too rapid.

(6) Primary control or stack switch throws burner into safety shutdown.

(a) A low voltage condition may have occurred. Check with a recording voltmeter for at least 24 hours, preferably longer.

(b) Check polarity of wiring. If connections are reversed or the hot line is where the ground should be, there is sometimes enough leakage through the control to cause a safety shut-down.

(c) See manufacturer's instructions with the primary burner control to insure that all adjustments within this control are correct.

(7) No oil appears at the nozzle.

(a) Fuel is too low in supply tank.

(b) Nozzle is plugged.

(c) Look for a leak in the suction line.

(d) Look for a leak in the vacuum gauge port.

(e) See that the pump shaft rotates.

(f) Look for a leak around the strainer gasket.

(g) Inspect for leaks at the pump shaft seal.

(h) If the preceding steps do not locate the problem, loosen the vent plug in the fuel unit (pump) and run the burner to see if fuel flows as far as the fuel unit. If fuel reaches the fuel unit the problem is within the fuel unit.

(I) If trouble is isolated to the fuel unit, it should be returned for repair.

e. Coupling adjustment. When installing the coupling between the pump and motor, check to see that there is no undue pressure on the pump shaft. If pressure exists, locate the coupling closer to the body of the fuel unit shaft.

f. Burner adjustment. An oil burner must deliver sufficient heat to provide for winter heating requirements, plus an amount sufficient to warm up a cold building in a reasonable period of time. If the oil burner is adjusted to provide a greater amount of heat than is necessary, the boiler or furnace will operate at a higher rate with consequent lower efficiency. After adjusting the oil rate to the heat requirement, regulate the draft and air quantity. An automatic draft regulator is necessary for proper burner operation. The lower the draft, the smaller the amount of air that will flow through the furnace or boiler when the burner is down. However, starting conditions require a draft in the firebox of about 0.03 to 0.06 inches water gauge. If it is impossible to obtain sufficient air for proper combustion with this draft, the draft in the firebox must be raised. After preliminary draft adjustment, adjust the quantity of combustion air to give the flame appearance and CO_2 recommended by the burner manufacturer. Use a flue gas analyzer to determine the carbon dioxide (CO_2) and a draft gauge for measuring the draft. It may be necessary to readjust the draft as a change in air supply affects the draft and vice versa. Carefully obtain a fair sample of flue gas for analysis as a leaky boiler or furnace setting may give a false indication of air used for combustion. The resulting flame should be clean and free from smoke. When the correct setting is determined, lock the adjustment points for air, oil, and draft to prevent change. When the burner has been adjusted, test all safety controls in accordance with the manufacturer' s instructions.

3-14. Fuel oil piping.

Figure 3-9 shows a typical arrangement of piping from the fuel oil tank to the oil burner.

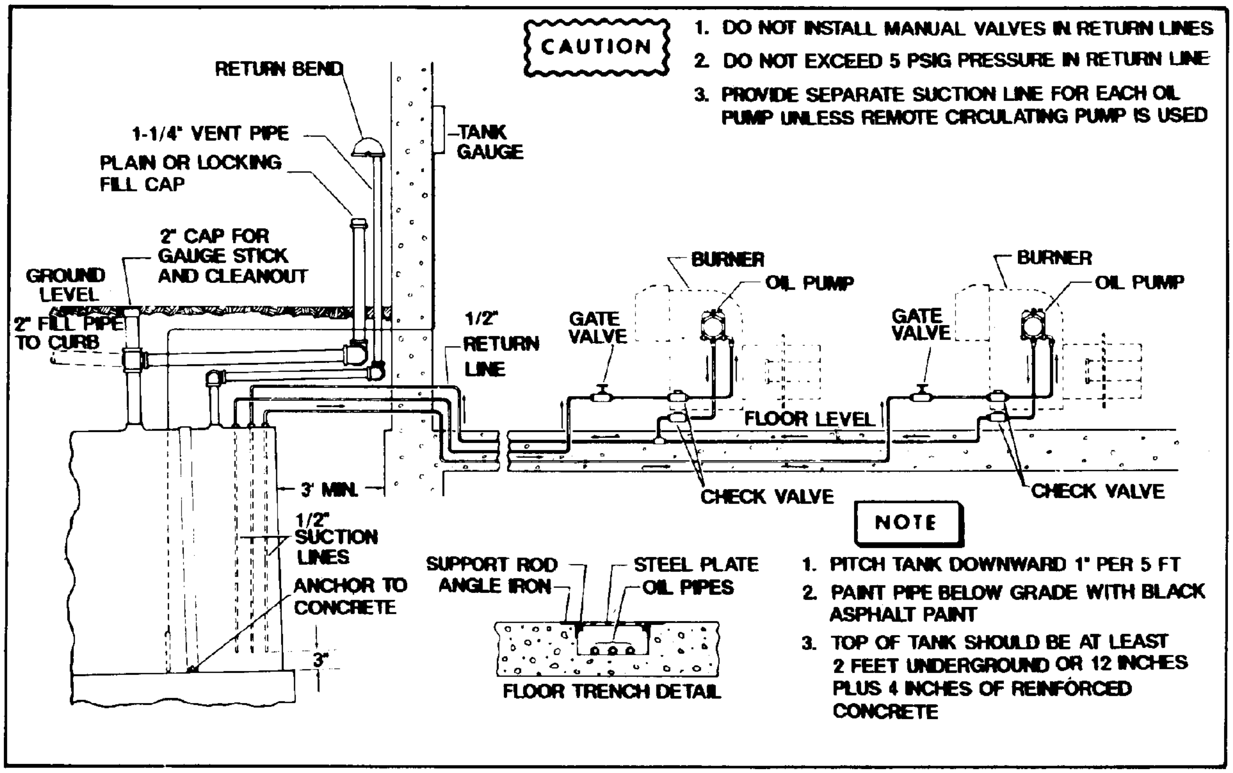

Figure 3-9. Typical fuel oil piping.

a. *Automatic oil shut-off* A thermomechanically or thermoelectrically actuated shut-off valve is provided in the oil supply line to stop oil flow in the event of a fire at the oil burner. The thermal detection device for the valve should be located directly above the oil burner. Figure 3-10 shows a lever gate valve designed for installation in connection with a wire and fusible link. When the fusible link releases at approximately 165F, the springloaded lever closes the valve, stopping oil flow to the burner.

Figure 3-10. Automatic oil shut-off valve.

b. Oil delay valve. Pressure atomizing type oil burners are equipped with an oil delay valve located between the oil pump and nozzle. The valve delays opening at least four seconds after the burner motor is energized and closes instantaneously when the motor is deenergized.

Section IV. GAS BURNERS

3-15. General.

Natural gas is an ideal fuel because it burns cleanly and easily, and requires relatively simple equipment. It is a comparatively dangerous fuel because it mixes easily with air and burns readily. Excercise extreme care to prevent or stop leakage of gas into an unlit furnace or the boiler room. In all gas installations, use only the type of burner which is best suited for the intended service and install in accordance with applicable standards.

3-16. Burner types with descriptions.

There are two basic categories of gas burners: atmospheric and forced draft. In both categories, gas is forced out of an orifice or tip (called a spud) by gas pressure in the line. The gas draws air along with it and is discharged into a specially shaped refractory tile. The gas and air are mixed and burned. Air may be supplied at atmospheric pressure (atmospheric burner), or the burner may be enclosed in a duct and air supplied under pressure (forced draft burner).

3-17. Operation procedures.

a. Radiant burners. Burners shown in figures 3-11 and 3-12 are known as radiant burners since in operation the tile becomes very hot and radiates heat to the incoming gas and air, resulting in a flame that burns close to the tiles. All of the air necessary for combustion passes through the tiles with the gas. This results in good combustion providing the tiles are not broken or obstructed and the gas tips or spuds are of the proper size to produce a uniformly mixed flame over the entire rectangular or circular shaped burner face. There is a tendency for this type of burner to have yellow streaks in the flame while operating at high-fire, and it is difficult to adjust them for maximum combustion efficiency. These burners operate at pressures up to 4 psig. The burner is usually mounted in the front or rear of the combustion chamber near the floor. Pilot lights are introduced through the refractory near the center.

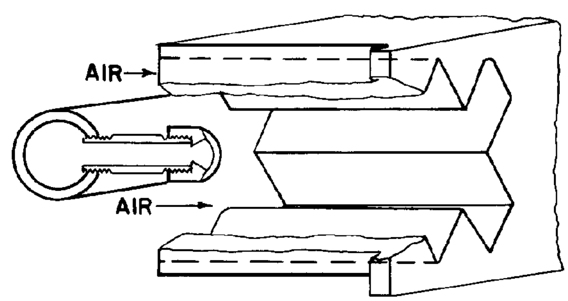

Figure 3-11. Individual low pressure gas burner.

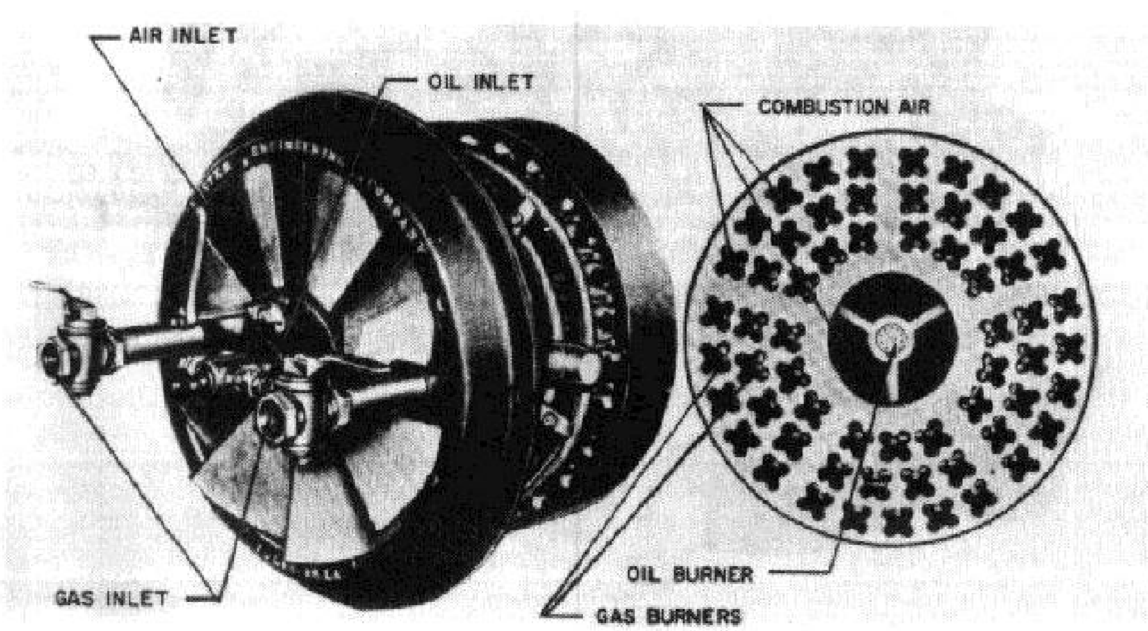

Figure 3-12. Assembly of low pressure gas/oil burner.

b. Up-shot burners. This type of gas burner uses a special venturi shaped tube casting mounted on the spud which projects up into the venturi. The top is enlarged to hold a standard 2¼ x 4½ x 9 inch firebrick. Air is drawn into the bottom of the venturi and mixed with gas. The mixture of gas and air strikes the bottom of the brick after passing through a small baffle which improves the distribution of the mixture, and escapes around the sides and edges of the brick. Two types of venturi tubes are in general use. In one, the brick is installed flat; in the other, the brick is supported on one of the long faces. A complete burner is made up of a number of these venturi units, arranged as shown in figure 3-13. The number used depends on the capacity of the boiler or size of the furnace. These burners operate at pressure up to 4 psig.

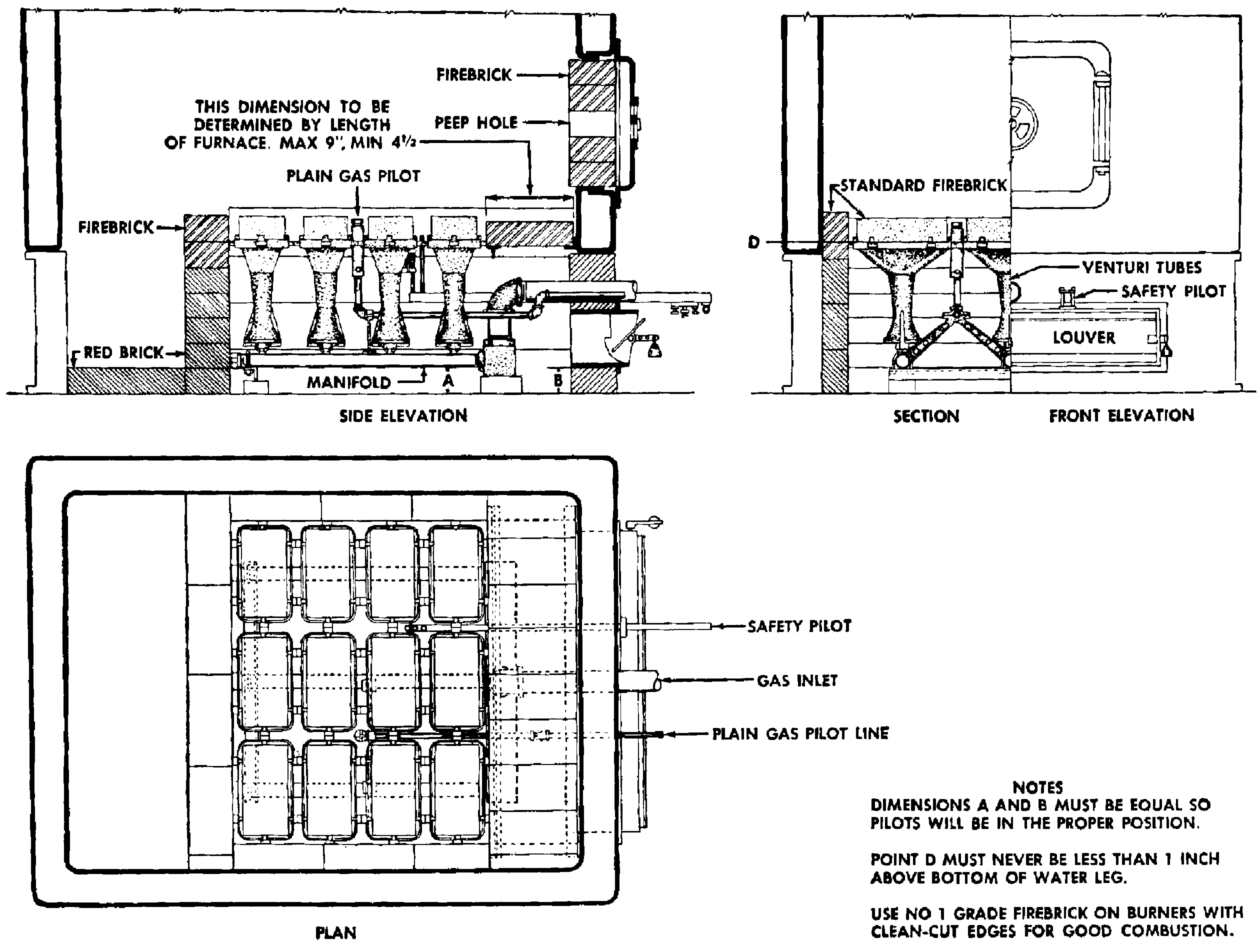

Figure 3-13. Typical installation of low pressure gas burner.

c. Mechanical mixing burners. This type of burner is extremely limited in use, but it does have the advantage of creating an intimate mixture of gas and air which permits operating through a wide range with a transparent flame without yellow streamers. The burner consists of a spider with the gas issuing from tangentially mounted orifices. The reaction from the expanding gas at these orifices causes the spider to rotate. The spider is mounted on a shaft which drives a combustion air blower. The spinning orifices on the spider create the effect of an infinite number of orifices, resulting in good, mechanical mixing of the air and gas. The characteristics of the driven fan are such that it delivers air through the burner throat in direct proportion to the amount of gas being used. The combustion controls on the gas supply must be gradual in response. Since the blower fan would not slow down immediately on a sudden drop in the gas supply, a temporary lean mixture would result and the flame would move out from the throat into the furnace. These burners operate at pressures from 1 to 30 psig.

d. Register burners. A register or multispud gas burner is most suitable when burning gas in combination with oil. The gas burner does not interfere with the oil burner, making it possible to burn gas or oil independently or at the same time. The burner consists of a circular gas ring or manifold, with numerous holes drilled on the furnace side. Gas from these holes mixes with incoming air at the throat of the burner. At light loads, the flame burns close in the throat of the burner. At high rates of firing however, there is a tendency for the gas to burn farther away from the throat, with the possibility of the flame blowing out entirely on sudden load fluctuations and improper draft regulation. Burners of this type vary in amount of gas pressure required, depending on the size of the drilled holes in the gas manifold; but generally a minimum gas pressure of 1 psig is required for good operation. See figures 3-14, 3-15, and 3-16.

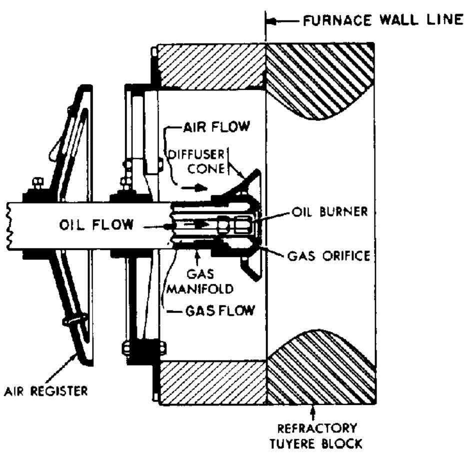

Figure 3-14. Register burner (gas orifices centered in air stream).

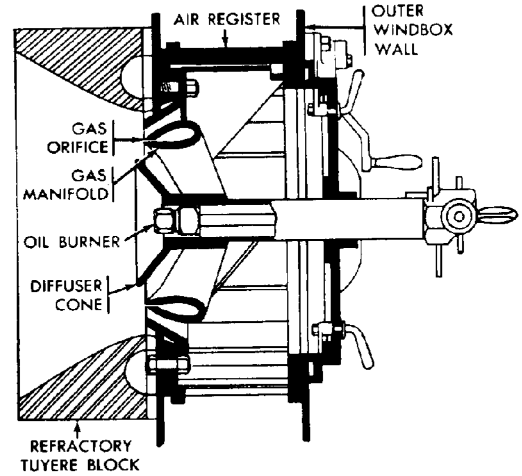

Figure 3-15. Register burner (gas manifold dividing air stream).

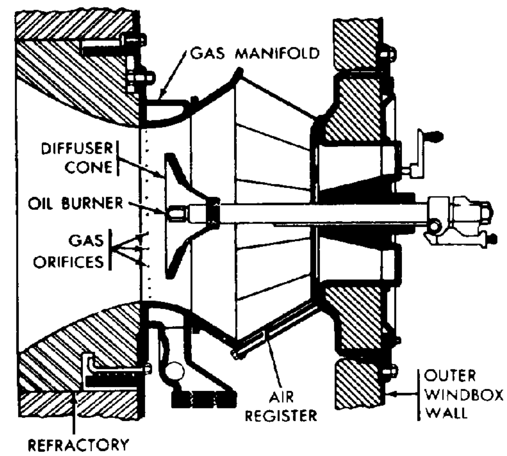

Figure 3-16. Register burner (gas orifices outside air stream).

3-18. Starting procedures.

The operation of gas burning equipment is simple, since the fuel is a gas which mixes intimately with air for combustion. Operation, however, can be hazardous, and the application of safety precautions cannot be overemphasized. The procedures given below must be followed in starting any gas fired equipment.

a. Make sure that the room in which the equipment is installed is free of gas which might have accumulated through leakage, accidental opening of a fuel valve, or failure of the pilot. Odorized gases may be detected by smell. Explosion meters can be used to detect the presence of gas in hazardous mixtures.

b. Inspect gas piping, valves, and controls to make sure that they are in good condition and in good working order.

c. Purge furnace by turning on the fan on forced draft burners. If natural draft, check flow of air and presence of any obstructions in flue and chimney passages.

d. Ignite burner as recommended by the manufacturer of the equipment.

3-19. Inspection and maintenance.

Safety is the principal consideration. Prevent leakage at all times; locate piping, valves, and controls to prevent damage or breakage. Figure 3-17 shows three typical fuel gas system schematics as approved by Factory Mutual System (FM), Factory Insurance Association (FIA), and Underwriters Laboratories, Inc. (UL). Provide adequate ventilation for removal of products of combustion. Inspect flues and chimneys for deterioration due to high moisture content of burned hydrogen. Chimneys should be moisture-proofed and smoke pipes replaced as required. Burning certain types of gases causes deposits in the burners and requires periodic burner cleaning. Refractories used in radiant type burners require routine inspection and periodic replacement. Consult manufacturer's manuals for specific operating instructions for the particular equipment used.

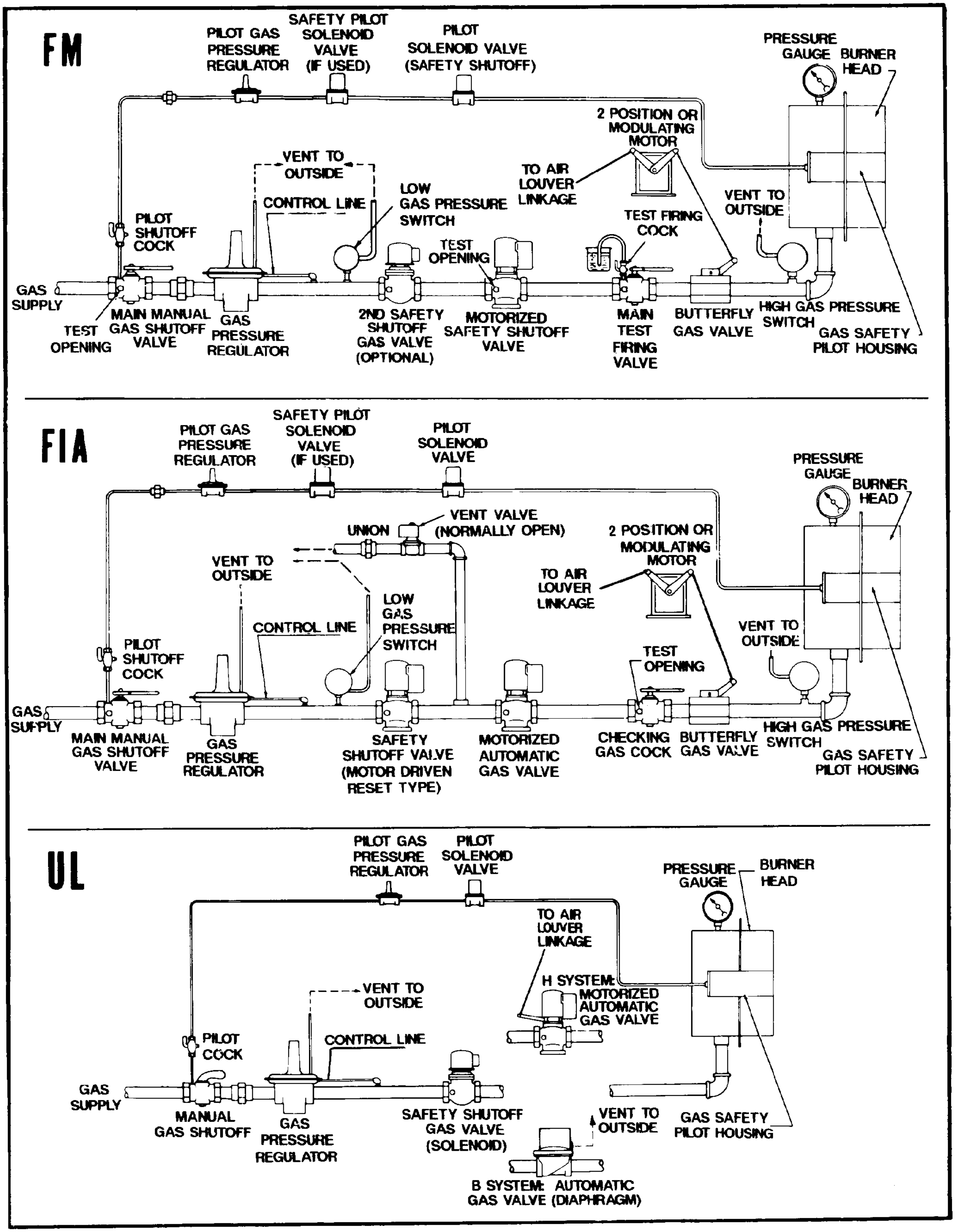

Figure 3-17. Typical fuel gas piping.

a. Flame. Inspect the burner periodically and note the appearance of the flame and gas pressures. A yellow flame indicates partially restricted air passages and the formation of carbon because of incomplete combustion.

b. Combustion chamber. Inspect the combustion chamber for evidence of burning papers and trash. Check the area directly in front of the burners for accumulated debris. Remove bricks and debris which affect the flame.

Section V. DUAL FUEL (OIL/GAS) BURNERS

3-20. General.

Since oil is required for standby service in most localities where gas burners are installed, it has been the practice to install oil burners to supplement the gas burners. Steam or air pressure atomizing oil burners are usually used with radiant gas burners. The application of a suitable oil burner to a multijet upshot gas burner is more difficult because the oil burner must be installed independently. Ring type gas burners readily lend themselves for use in combination with oil. Mechanical mixing burners are also manufactured with steam atomizing oil burners, using steam for the reaction in the absence of gas.

3-21. Operation.

The nozzle-mixing type burners, where air and gas flow separately and mix just before entering the furnace, are widely used as combination burners. The incoming air stream is usually supplied by a forced draft fan. Total air flow is controlled by duct dampers or fan speed. Burner air registers are used to control flame shape and are not intended to regulate air flow rate. Individual burner gas valves should be wide open when using gas as the fuel. Gas flow quantity and pressure should be controlled by a control valve at the header inlet.

3-22. Inspection and maintenance.

Inspection and maintenance procedures are identical to those described for individual oil burners and individual gas burners in this chapter.

Section VI. ENERGY CONSERVATION

3-23. Adjustments to excess air.

a. General. In theory, combustion of oil, gas, or coal requires a given fuel/air ratio for complete burning and maximum efficiency. In practice, air is used to provide the necessary oxygen for combustion and must be supplied in excess of theoretical requirements to ensure complete combustion. The minimum quantity of air that will provide complete combustion is the optimum amount. Too little air prevents complete combustion and wastes fuel. Too much air reduces the rate of heat transfer to the boiler and furnace, and consequently increases the amount of heat lost out of the stack. It is important, therefore, that airflow into the com bustion chamber be controlled to achieve the most favorable fuel/air ratio for any given firing rate. The burner/furnace efficiency nomograph, figure 3-18 correlates stack temperature, stack gas analysis, and boiler or furnace efficiency for natural gas and No's 2 and 6 oil. Maximum efficiency occurs where %CO and %O_2 are at a minimum and %CO_2 is at a maximum. As demonstrated by figure 3-18, this occurs with 0% excess air. Some minimum quantity of excess combustion air is required, however, to assure complete combustion despite incomplete fuel and air mixing and load or draft instabilities.

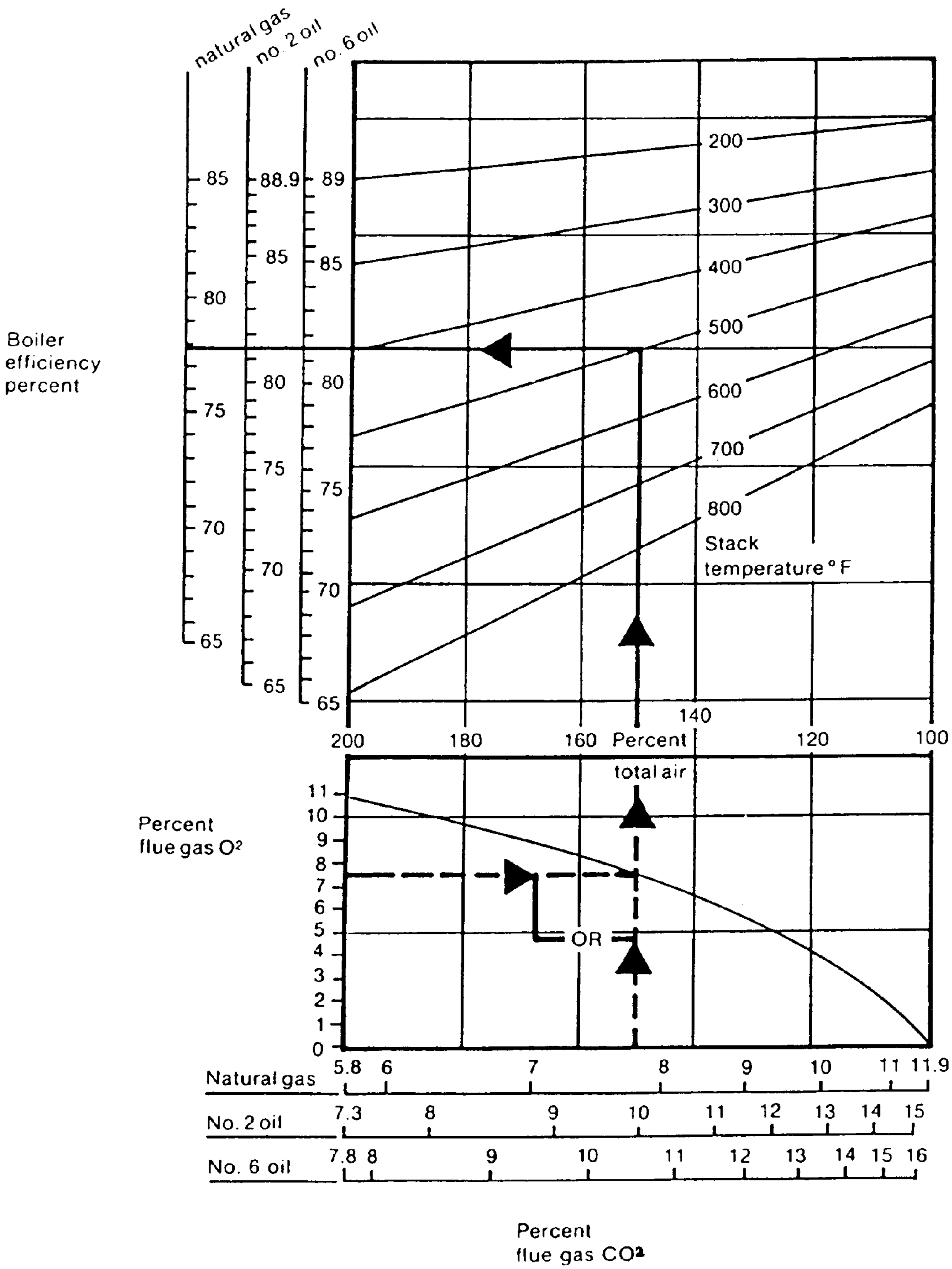

Figure 3-18. Combustion efficiency chart.

b. Stack gas analysis.

(1) Taken together, the percentage of carbon dioxide (CO_2) or oxygen (02) contained in the stack gas and the stack gas temperature determine the combustion efficiency, as shown in figure 3-18. Use a combustion analyzer to check the CO_2 content of the flue gas and a thermometer to check the flue gas temperature. Both stack temperature and stack gas analysis should be taken at the same point (preferably at a point just after the last heat recovery device) to minimize errors due to stack gas cooling and air infiltration.

(2) A more accurate measure of combustion efficiency is obtained by an analysis of the oxygen content (%O_2) rather than the content of other gases such as carbon monoxide (CO) or carbon dioxide (GO_2). As shown in figure 3-18, the cross-checking of oxygen concentrations is useful in judging burner performance more precisely. Furthermore, due to the increasing use of multifuel boilers, O_2 analysis is the single most useful criterion for all fuels since the O_2 to total air ratio varies only within narrow limits.

(3) Clean and monitor burners each year to assure optimum efficiency. Adjust burners whenever necessary. In large installations, make combustion monitoring and control a daily procedure.

c. Tune-up and manual control.

(1) Boilers and furnaces may achieve relatively high instantaneous full-load efficiencies (80%-90%), but because they are operated most of the time at part load, they have lower seasonal efficiencies. Generally, measures which increase the full load instantaneous efficiency will also increase the seasonal efficiency. When peak loads are of very short duration, however, it may be advantageous to tune the boiler for maximum efficiency at part load conditions in order to gain greater seasonal efficiency.

(2) Figure 3-19 depicts a typical part load ratio versus time curve for a boiler or furnace installation. In this example, the heating system operates between 50% and 60% of full load for more hours per year than at higher or lower loads. The optimum operating point of the heating system should be selected accordingly to give the highest efficiencies over this range. Examine previous load records to determine the optimum operating points to use when tuning an existing heating system.

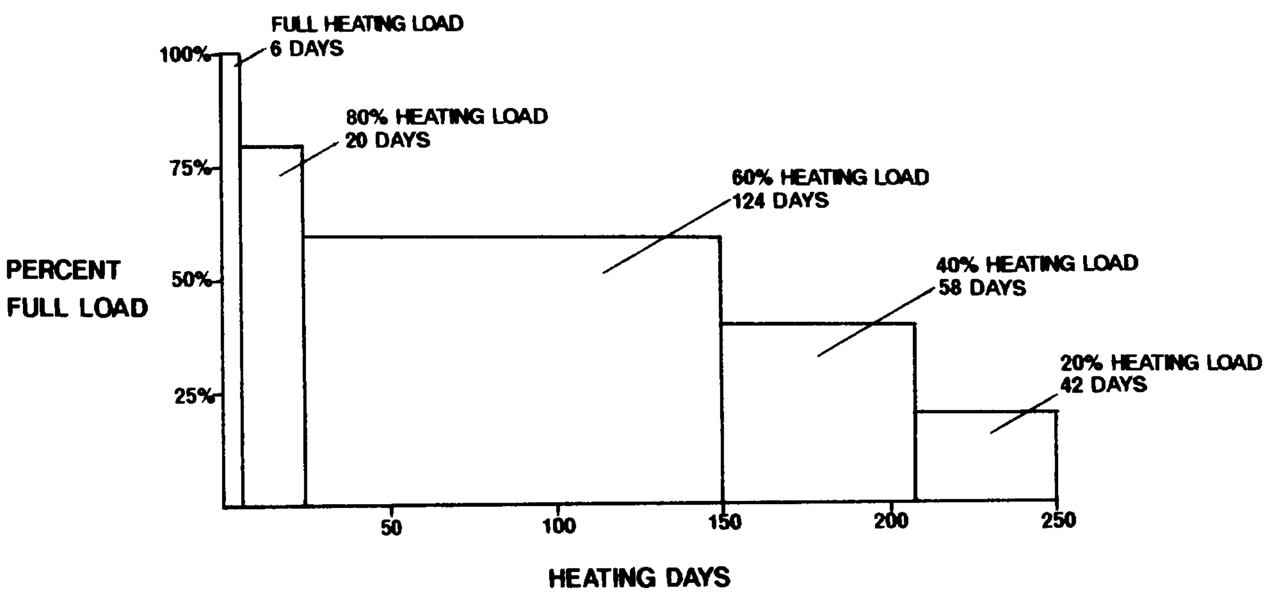

Figure 3-19. Typical heat load distribution.

(3) Devices are available which continuously measure and integrate CO_2 or O_2 concentration and stack temperature to produce a direct reading of boiler efficiency. These indicators provide boiler operators with the requisite information for manual adjustment of the boiler fuel/air ratio.

d. Automatic control. Optimum combustion efficiency, which varies continuously with changing loads and stack draft, can be achieved only through a continuous analysis of the flue gas. The information required for continuous monitoring and adjustment of the fuel/air ratio is flue gas temperature and %O_2 or %CO_2. For larger boilers, consider the installation of an automatic continuous oxygen analyzer with "trim" output that will adjust the fuel/air ratio to meet changing stack draft and load conditions. Most boilers can be modified to accept automatic fuel/air mixture control by flue gas analyzer, but a gas analyzer manufacturer should be consulted for each particular installation to be certain that existing boiler controls are compatible with the proposed analyzer.

e. Burner retrofit. With the advent of more costly oil, many burners are being retrofitted to achieve better atomization and mixing of air and fuel. This allows more complete combustion, less soot and smoke, less cleaning, and better combustion efficiency. Oil burners that cannot achieve O_2 readings down to 5% excess without causing smoke (or high CO in the case of gas burners) are candidates for replacement. Modern replacement burners are capable of more efficient atomization of oil or mixing of gas with combustion air.

f. Reduce leakage. Primary and secondary air should be allowed to enter the combustion chamber only in regulated quantities and only at the correct location. Defective gaskets, cracked brickwork, broken casings, etc. will allow uncontrolled and varying quantities of air to enter the boiler and will prevent accurate fuel/air ratio adjustment. If spurious stack temperature and/or oxygen content readings are obtained, inspect the boiler for air leaks and repair all defects before making a final adjustment of the fuel/air ratio.